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Producing Target Models at a Central Facility

Assessment Methodology

Myron Hura, Gary McLeod

Project AIR FORCE

The research reported here was sponsored by the United States Air Force under Contract F49620-91-C-0003. Further information may be obtained from the Strategic Planning Division, Directorates of Plans, Hq USAF.

Library of Congress Cataloging in Publication Data

Hura, Myron
Producing target models at a central facility : assessment methodology / Myron Hura, Gary W. McLeod.
p. cm.
"Prepared for the United States Air Force."
"MR-425-AF."
Includes bibliographical references.
ISBN 0-8330-1550-8
1. Precision guided munitions—United States. 2. Target acquisition—Evaluation. I. McLeod, Gary W. II. United States. Air Force. III. RAND. IV. Title.
UF513.H873 1994
358.1'7—dc20 94-19225
CIP

Published 1994 by RAND
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
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PREFACE

This report develops a methodology for assessing the capabilities of a notional central facility to support the detailed terminal-area mission planning—in particular, building target models—required by autonomous precision-guided weapons (PGWs) with target-imaging sensors. Specifically, this work defines the functions that a central facility has to perform to build target models, provides representative time estimates for completing those functions, and then determines daily production rates for target models under a range of conditions.

To place the methodology in the context of existing organizations, existing systems, and potential new capabilities, the report defines three alternative designs for a central facility. The central facility concept is the initial building block for the alternative intelligence-support and mission-planning architectures for autonomous PGWs described in a companion report (Hura and McLeod, 1993), in that it provides additional information on the ability of a notional central facility to produce target models. Although the focus is on autonomous PGWs with imaging infrared sensors, much of the methodology for building target models also applies to other target-imaging sensors.

This research is in direct support of the Air Force Intelligence Support Working Group responsible for developing the Intelligence Support Plan for advanced PGWs. This work should also be of interest to decisionmakers responsible for developing the intelligence-support and mission-planning infrastructure for this category of weapon.

The study was sponsored by the Air Force Assistant Chief of Staff for Intelligence (AF/IN) and was performed within the Force Modernization and Employment Program of Project AIR FORCE, a federally funded research and development center at RAND.

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SUMMARY

To support the employment of autonomous precision-guided weapons (PGWs) with target-imaging sensors, the intelligence and mission planning communities will have to build target models;[1] this support requires substantial effort and expertise. Because existing autonomous PGWs, such as the Navy Tomahawk cruise missile, do not require this type of support, these communities may be unfamiliar with the functions and the timelines for developing target models. Without a good understanding of the functions and the timelines to complete these functions, the intelligence and mission planning communities will be unable to develop an infrastructure to adequately support the responsive employment of this category of weapon.

The objective of this report is to develop a methodology for assessing the ability of a notional central facility to build target models to support the employment of autonomous PGWs with target-imaging sensors. As discussed in a companion report (Hura and McLeod, 1993), the notional central facility is the initial building block for the alternative intelligence-support and mission-planning architectures that could be developed to support the employment of this category of PGW.

To place the methodology in context of organizations, systems, and operating protocols, this report characterizes three alternative de-

[1]A target model is a representation of the target and nearby objects that is used to support target acquisition by the PGW's target-imaging sensor and autonomous target-acquisition algorithm.

signs for a notional central facility. Two designs build on the capabilities of existing *centralized* intelligence facilities,[2] such as the 480th Intelligence Group, Langley AFB, Virginia, and the third builds on the new capabilities being fielded at Cruise Missile Support Activities, one located at the Atlantic Intelligence Command, Norfolk, Virginia, and the other at Camp Smith, Hawaii, that support the data preparation and mission planning of Navy Tomahawk cruise missiles.

Because autonomous PGWs with target-imaging sensors have not completed development, there is very limited experience in building target models that will adequately support their employment. Consequently the estimated timelines for actually building target models presented in this report are only *rough estimates*. We derived the estimated timelines from discussions with weapon developers, from visits to intelligence and mission planning activities, by observing imagery analysts geoposition and mensurate imagery,[3] and by reviewing selected literature on imaging sensors.

FUNCTIONS AND TIMELINES FOR BUILDING TARGET MODELS

The end-to-end process for building target models is complex and consists of the following functions: (1) imagery collection, (2) targeting, (3) geopositioning and mensuration of imagery, (4) building target models (concept formulation, formatting and entering data into target folders), and (5) quality control. The timelines for completing these tasks vary widely. Because of the complexity of these tasks, and the variation of times required to complete the tasks, the methodology for assessing the capabilities (both systems and personnel) of facilities to support target-model building must explicitly consider

[2]Because there are only a few of these facilities and they are usually associated with a U.S. unified command (often reporting to the chief of staff for intelligence), we use the term *centralized* to describe them.

[3]*Mensuration* is the application of geometry to the computation of lengths, areas, or volumes from given dimensions and angles. In the case of imagery mensuration, these given dimensions and angles include, for example, the location of the sensor, the location of the particular object, and the angles subtended at the sensor by the object's physical dimensions.

each of the functions and develop time estimates to complete these functions under a range of conditions.

An understanding of these functions and the variations in their timelines are important in developing a notional central facility that will support the responsive employment of autonomous PGWs with target-imaging sensors. If the required imagery is not available, as could be the case for emergent targets in a no-warning conflict, the collection function dominates the timeline for producing target models. Given highest priority and weather permitting, the requisite imagery can be collected in about two days. This may occur for high-priority targets that are not identified before the start of a contingency. Under routine priority, collection can take several months.

On the other hand, if imagery is available, as would be the case for preplanned targets known well in advance of hostilities, building target models would be the time-dominant function, ranging from about 2.5 hr for simple targets using future systems (hardware and application software) to 11 hr for complex targets using existing systems.[4]

ALTERNATIVE CENTRAL FACILITY DESIGNS

Several centralized intelligence organizations have procedures or systems that can perform most of the functions necessary to build target models for autonomous PGWs with target-imaging sensors. Examples of these facilities are the 480th Intelligence Group (IG) at Langley AFB, Virginia, the Atlantic Intelligence Command (AIC) at Norfolk, Virginia, the Joint Intelligence Center, Pacific (JICPAC) at Hickam AFB and at Makalapa, Hawaii, and the Joint Analysis Center (JAC) at Molesworth, England. These organizations only lack procedures for building target models (currently being developed by PGW contractors) and trained personnel to accomplish the necessary tasks. Appropriate protocols will have to be developed to allow trained personnel access to imagery databases and to imagery mensuration and geopositioning systems.

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[4]Simple targets are those located in relatively uncluttered scenes (i.e., areas with few structures or objects in the vicinity of the target). Complex targets are those located in cluttered scenes such as urban areas.

If a notional central facility were created at one of the above centralized intelligence organizations, it could produce enough target models, using existing systems, to support roughly 4 to 11 missions per day against preplanned targets, with the lower number for complex targets requiring multiple PGWs and the higher number for simple targets requiring a single PGW. Alternatively, after an initial startup delay of 2 days for imagery collection, such a facility could support roughly 6 to 19 missions per day against comparable emergent targets. The development of this capability would require an investment of about \$0.6 million for additional systems and the commitment of about \$3.1 million per year for system support and personnel costs.

If the daily production capability just described is not sufficient to satisfy operator needs, then the number of missions per day can be doubled, for example, or tripled by doubling (or tripling) the procurement cost and the annual system support and personnel costs. Depending on which organization ultimately funds this production capability, the costs may be viewed as either insignificant or exorbitant. Certainly these costs may seem small when compared to the costs usually associated with a major weapon acquisition program.

If the notional central facility were provided with advanced systems, such as a digital imagery workstation with application software for mensuration and geopositioning and improved procedures or systems (e.g., expert systems or, perhaps, systems based on artificial intelligence) for building target models, it would be able to support 8 to 23 missions per day against preplanned targets, or 11 to 39 missions per day against emergent targets. The system procurement cost for this future capability would be about \$1.0 million with annual system support and personnel costs of \$3.2 million. The cost estimate for system procurement assumes that the cost of developing improved procedures for building target models are included in PGW development costs. Again, these production rates can be increased, if the procurement cost and annual support and personnel costs are also increased proportionately.

Alternatively, a notional central facility could be built using the capabilities of the new Digital Imagery Workstation Suite (DIWS) being fielded at the U.S. Pacific Command (PACOM) and the U.S. Atlantic Command (USACOM) Cruise Missile Support Activities (CMSAs).

The CMSAs currently support the mission planning of Navy Tomahawk cruise missiles. As in the case of the centralized intelligence organizations, the CMSAs would require new procedures and trained personnel for building target models. Provided with these capabilities, a notional central facility at a CMSA would be able to produce as many target models as the notional central facility built at a centralized intelligence organization that is equipped with future systems. The annual system support and personnel costs of this notional facility would be comparable to the one built around the central intelligence facility with future systems. The system procurement cost would depend on the number of workstations that the CMSA would have to procure to support the building of target models.

Because this analysis did not examine employment concepts for autonomous PGWs with target-imaging sensors, we choose not to recommend a preferred central facility option nor to define production requirements. Nevertheless, the research described here will assist the operators and the intelligence and mission planning communities in their dialogues to define the appropriate intelligence-support and mission-planning architecture to support this category of PGW. Certainly, the selection of the preferred central facility option should be based primarily on the planned operational concept, but should also take into consideration budgetary and personnel constraints. *We recommend that Air Force and Navy operators, intelligence personnel, and mission planning personnel closely examine the alternative central facility options described here, and that each service determine which option, if any, should be pursued.*

ACKNOWLEDGMENTS

The authors would like to thank Captain David Anthony (Hq ACC/INXI) from Headquarters, Air Combat Command, and Captain Michael Lancaster (Hq USAF/INXA) from Headquarters, Air Force, for their reviews and comments on an earlier draft of this report. We are also indebted to our RAND colleague Richard Mesic for his useful insights and suggestions on this research.

ACRONYMS

AF	Air Force
AFMSS	Air Force Mission Support System
AIC	Atlantic Intelligence Command
APPS	Analytical Photogrammetric Positioning System
ATO	Air tasking order
A/W/E	Aircraft/weapon/electronic
A/W/E+	Aircraft/weapon/electronic (advanced capability)
AWS	Advanced workstation
BTG	Basic Target Graphic
CATIS	Computer-Aided Tactical Information System
CCT	Computer compatible tape
CINC	Commander in chief
CIO	Central Imagery Office
CMSA	Cruise Missile Support Activity
CONUS	Continental United States
DIA	Defense Intelligence Agency
DIWS	Digital Imagery Workstation Suite
DMA	Defense Mapping Agency
DPPDB	Digital Point Positioning Data Base
DSMAC	Digital Scene Matching Area Correlator
HC	Hard-copy
IDEX	Imagery Data Exploitation System
IDI	Image Data Input
IDS	Image Data Storage
IG	Intelligence group
INS	Inertial navigation system
JAC	Joint Analysis Center
JIC	Joint Intelligence Center

JICPAC	Joint Intelligence Center, Pacific
LCWS	Low-cost, digital imagery workstation
LTMS	Light Table Mensuration System
PACOM	U.S. Pacific Command
PGW	Precision-guided weapon
PP	DMA Points Program
PPDB	Point Positioning Data Base
QC	Quality control
RPC	Rapid Positioning Capability
SC	Soft-copy
SR	Shared Resource
TBIP	Tomahawk Block Improvement Program
TENCAP	Tactical Exploitation of National Capability
TERCOM	Terrain Contour Matching
TMWS	Target Material Workstation System
TMWS+	Target Material Workstation System (upgrade)
USACOM	U.S. Atlantic Command
VLDS	Very large data storage
WS	Workstation

Chapter One

INTRODUCTION

This report provides a preliminary assessment of the ability of a notional central facility to build target models to support autonomous precision-guided weapons (PGWs) with target-imaging sensors. A target model is a representation of the target and nearby objects that is subsequently transformed by the PGW's terminal guidance system into a format or structure, called a template. This template is directly usable by the terminal guidance system's autonomous target-acquisition algorithm—a correlation algorithm that compares the template to the scene actually imaged by the PGW's target-imaging sensor. Once the target is acquired by the algorithm (i.e., its location is identified in the image), the PGW then *homes* on the target.

A general discussion of alternative intelligence-support and mission-planning architectures for autonomous PGWs is provided in a companion report (Hura and McLeod, 1993). This report provides additional information regarding the target-model production capabilities of a primary element of these alternative architectures, namely, the central facility.

As discussed in Chapter Two, a few existing *centralized*[1] intelligence organizations within CONUS and at developed theaters support many of the functions required by autonomous PGWs with target-imaging sensors; these could play the role of a central facility for building target models. Alternatively, two Cruise Missile Support

[1]Because there are only a few of these facilities and they are usually associated with a U.S. unified command (often reporting to the chief of staff for intelligence), we use the term *centralized* to describe them.

Activities used in planning missions for Navy Tomahawk cruise missiles could assume this role.

We caution the reader that the timeline values presented in this report for completing functions required to build target models are only *rough estimates.* However, because we derived the estimated values from discussions with weapon developers, from visits to intelligence and mission planning activities, by observing imagery analysts geoposition and mensurate imagery,[2] and by reviewing selected literature on imaging sensors, we believe that the results described here will be useful in our discussion of the potential capabilities of a central facility configured with either existing or improved systems. Because of the limited experience in building target models for autonomous PGWs with target-imaging sensors, these numerical values should be validated as part of the developmental and operational testing program for the particular weapon system.

A variety of target-imaging sensors have been proposed for this category of autonomous PGW: synthetic aperture radar, laser radar, imaging infrared sensor, and dual-mode concepts such as an imaging infrared sensor combined with a laser radar or a millimeter-wave radar. Because of the differences in these sensors and their associated autonomous target-acquisition algorithms, the target models (and target templates) will also be different. Although this report focuses on imaging infrared sensors, the overall methodology should be useful in examining target-model building for other sensors as well.

By defining alternative designs for a notional central facility, Chapter Two of the report places the methodology for assessing the capabilities of a notional central facility in the context of existing organizations, systems, and operating protocols. Chapter Three of the report discusses the estimated timelines for completing all the functions required to build target models for incorporation into target folders for preplanned targets. The estimated timelines for building target

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[2]*Mensuration* is the application of geometry to the computation of lengths, areas, or volumes from given dimensions and angles. In the case of imagery mensuration, these given dimensions and angles include, for example, the location of the sensor, the location of the particular object, and the angles subtended at the sensor by the object's physical dimensions.

models for emergent targets are presented in Chapter Four. Based on the timelines given in Chapters Three and Four, the estimated production capability of the notional central facilities to build target models for both preplanned and emergent targets is presented in Chapter Five. Chapter Six provides rough estimates of the initial system procurement and annual support costs for the central facility options. Key observations derived from the research are then summarized in the final chapter of the report.

Chapter Two

ALTERNATIVE CENTRAL FACILITY DESIGNS

The design of a notional central facility must take into account all the functions necessary to build target models. As discussed in more detail in Chapter Three, these functions include data collection, targeting, geopositioning, mensuration, building target models, and quality control. Moreover, the design should define the systems, personnel, and operating protocols that will be used to build target models. This chapter first describes the capabilities of existing centralized intelligence facilities and then describes three alternative designs for a notional central facility to support production of target models. Two designs build on the resident capabilities at several centralized intelligence exploitation[1] facilities and centralized target material production facilities. The third builds on the capabilities of existing Cruise Missile Support Activities (CMSAs) used in the mission planning of Navy Tomahawk cruise missiles.

CAPABILITIES OF CENTRALIZED INTELLIGENCE FACILITIES

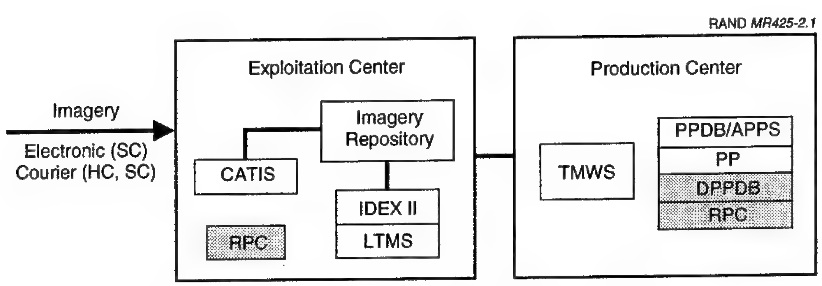
Several centralized intelligence exploitation facilities and target material production facilities possess systems that could be used for building target models for autonomous PGWs with target-imaging

[1]The terms *exploitation* and *exploit* are used throughout this report, usually in the context of imagery exploitation. As used here and by the intelligence community, exploitation is the detailed analysis of all types of source material (including documents, imagery, electronic intercepts, and hardware) collected, both overtly and covertly, by intelligence systems or personnel to derive specific types of data not readily available by other means.

sensors. Examples of these facilities are the 480th Intelligence Group (IG) at Langley AFB, Virginia, the Atlantic Intelligence Command (AIC) at Norfolk Naval Base, Virginia, the Joint Intelligence Center, Pacific (JICPAC) at Hickam AFB and at Makalapa, Hawaii, and the Joint Analysis Center (JAC) at Molesworth, England. Some of the systems used in these centralized facilities are illustrated in Figure 2.1, which describes an imagery exploitation center and a target material production center combined within one facility.

The exploitation centers receive imagery (and the corresponding imagery support data) collected by national sensors in both hard-copy (HC) and soft-copy (SC) formats. Imagery analysts use application software hosted on the Computer-Aided Tactical Information System (CATIS) for imagery database management, exploitation task management, and report generation and dissemination. For example, CATIS is used to locate imagery resident in the repository and to assist in staging the imagery to the exploitation systems. If imagery for the area of interest has been collected but is not resident at their location, the analysts can use CATIS to request that imagery. If imagery has not been collected for a particular target of interest, the analysts can use CATIS to request imagery collection.

To exploit the intelligence data resident in soft-copy imagery, analysts use the workstation associated with the Imagery Data Exploitation System (IDEX II). In particular, using this digital im-



NOTE: Shading indicates new systems or those under development.

Figure 2.1—Combined Imagery Exploitation and Target Material Production Facility

agery workstation, they can mensurate very accurately the length, width, height, and orientation (usually, the angle with respect to north of the principal horizontal axis) of any structure.[2] Although the workstation can display stereo imagery if available, all object mensuration is done on monoscopic imagery. Therefore, the determination of relative elevation, for example, between an offset aimpoint and a target is inaccurate (however, relative accuracy in the horizontal plane is very good). For exploitation of hard-copy imagery, imagery analysts use the Light Table Mensuration System (LTMS). However, using the support data provided with the imagery, neither IDEX II nor LTMS can perform accurate absolute geopositioning of targets or other objects of interest.

At the production center, target material builders use CATIS to determine the availability and quality of imagery or to request imagery if it is not available. The imagery is exploited on the IDEX II workstation or LTMS and then hard-copy imagery is scanned for digital input to the Target Material Workstation System (TMWS). If appropriate hardware and software are procured, soft-copy imagery can be input directly to the TMWS. In addition, future upgrades of TMWS will likely include imagery mensuration and geopositioning software.

The TMWS, developed under a Defense Intelligence Agency (DIA) initiative, provides an automated capability to produce tactical target materials, such as Basic Target Graphics (BTGs), or specialized target graphics. Before TMWS was developed, target materials were produced manually with the assistance of photo labs. The mensurated coordinates depicted on BTGs are usually obtained from fully geocoded imagery in which the absolute position in Earth coordinates of each point in the image is known or can be computed.

An example of fully geocoded imagery is the Defense Mapping Agency's (DMA's) Point Positioning Data Base (PPDB), which is a set of high-resolution national imagery stereo pairs (a series of pairs of film chips).[3] The analyst uses the Analytical Photogrammetric Positioning System (APPS), a stereo comparator light table, to read

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[2]It is difficult to measure accurate heights if only near-nadir imagery is available. In this case, off-nadir imagery is required.

[3]The area coverage of a standard PPDB is a square measuring 60 nautical miles on each side.

accurate coordinates of identifiable features from PPDBs. Because of long production timelines, PPDBs typically do not contain current imagery and have limited worldwide coverage.[4]

The current hard-copy PPDBs are not user-friendly: They require skilled APPS operators, a vibration-free environment, and a setup time of approximately 30 minutes. To alleviate these problems and to meet the increasing demands by the services for soft-copy (digital), accurate point-positioning products, DMA is developing the Digital PPDB (DPPDB). DPPDBs will be displayed on a digital imagery workstation with stereo viewing capabilities (if necessary, the digital image pairs could be displayed side by side on a monoscopic monitor). The workstation will enable rapid readout of mensurated coordinates. If the appropriate software is developed, object mensuration could also be performed.

DMA expects production of DPPDBs to begin in 1995. Because of production timelines, DPPDBs (like PPDBs) will not contain the most current imagery; thus, depending on the application, the imagery may be outdated. However, newly collected national, theater, or tactical imagery can be registered to DPPDBs, assuming the new imagery is available in digital format. If a target of interest appears on the new image, but not on the DPPDB, the target's location can still be accurately mensurated. Hard-copy PPDBs can also be used to register new imagery; however, the process is more complicated.

Accurate coordinates of specific targets also can be obtained directly from DMA through its Points Program (PP). DMA provides this service because existing PPDBs do not cover all regions of interest or the source of the coverage is based on old imagery. DMA provides this service in response to users requiring the most accurate coordinates available from the recognized authority, or simply because the users do not have access to an APPS. The accuracy of the mensurated coordinates is usually better than those from PPDBs, because DMA uses stereo comparators that are more precise than the APPS and because DMA has access to the best-available imagery to derive the mensurated coordinates.

[4]Although coverage is limited, PPDBs are concentrated in target areas of past, high national interest, and many of these areas are of current interest.

Because the imagery available for exploitation on IDEX II and LTMS is not accurately geopositioned using the accompanying support data, the Central Imagery Office (CIO), in conjunction with DMA, is developing a new capability known as Rapid Positioning Capability (RPC). The imagery received by the centralized intelligence facilities is the same; however, the RPC support data accompanying the imagery enable more accurate geopositioning. At this time, it is not certain which digital imagery workstations will host RPC, although the IDEX II and TMWS workstations are likely candidates. For hard-copy imagery, RPC most likely will be added to LTMS.

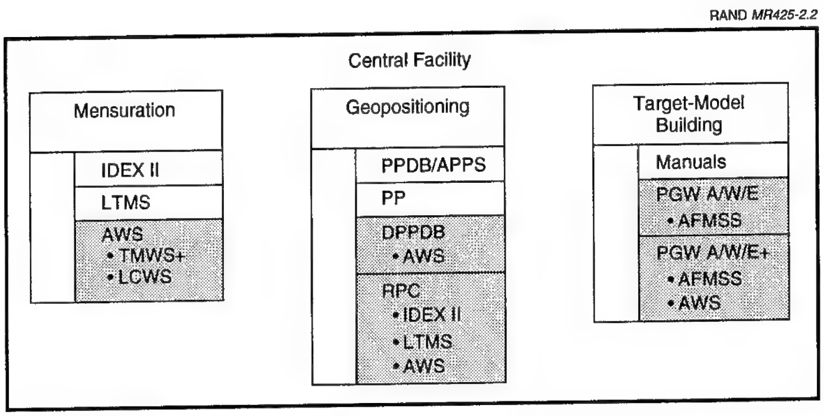
Absolute positioning using RPC is not expected to be as accurate as that using PPDBs or DPPDBs; however, it may be sufficient to support some precision-guided weapon concepts employing target-imaging sensors. For monoscopic imagery, the RPC relative horizontal accuracy is equivalent to that of PPDBs, but the relative vertical accuracy is very dependent on the quality of the underlying terrain data. Vertical accuracies (both absolute and relative) can be improved if stereo imagery with RPC data are available.

If funded, RPC will provide an additional geopositioning capability during contingency, crisis, and wartime operations, and a limited capability for regions without PPDB, DPPDB, or archival imagery coverage.

DESIGN OPTIONS BASED ON CENTRALIZED INTELLIGENCE FACILITIES

Using existing systems available at the centralized intelligence facilities, a central facility for building target models could be configured, as shown in Figure 2.2. Future systems capabilities are also depicted (indicated by the shading).

Under this concept, the central facility would rely on soft-copy imagery received by the exploitation center to build target models. Trained personnel would perform the targeting function by displaying the imagery on IDEX II. Mensuration of objects of interest would also be done on IDEX II. In case the imagery is available in hard-copy only, an LTMS should be included in the facility.



NOTE: Shading indicates new systems or those under development.

Figure 2.2—System Capability at a Central Facility

If TMWS is upgraded to include imagery mensuration and geopositioning software (indicated by TMWS+), then it could be used in place of IDEX II. Similarly, if a prototype low-cost, digital imagery workstation (LCWS) from the TALON SCENE initiative[5] is made available, then it could also be used in place of IDEX II. These two possibilities are indicated by the advanced workstation (AWS) on Figure 2.2. Note that the large imagery repository supporting the IDEX II workstation is still required.

Analysts would rely on APPS and hard-copy PPDBs to derive accurate geopositioning data. If PPDBs are not available or not current enough, then analysts would obtain mensurated coordinates from DMA's Points Program. In the near future, analysts will be able to obtain mensurated coordinates from DPPDBs, assuming that a workstation (e.g., an AWS) with the capability to display stereo imagery is made available.

The only capability not resident at these centralized intelligence organizations is the procedures for building target models. Currently, this is not an automated process; builders of target models will have

[5]This initiative is sponsored by the Air Force Tactical Exploitation of National Capability (TENCAP) office.

to rely on manuals containing procedures for building target models and on substantial amounts of training. The data obtained from the process would then be entered into a target folder.

If the facility is equipped with an Air Force Mission Support System (AFMSS), the data could be entered into the particular PGW's aircraft/weapon/electronic (A/W/E) software module (A/W/E is shaded in Figure 2.2 because such a module currently does not exist). The target-model data, formatted for the particular PGW, could then be downloaded onto a soft-copy medium for storage in a target folder (in this case, AFMSS must be able to import and export target models via this medium).

In the future, improvements in building target models could be gained by the addition of advanced application software based on expert systems or artificial intelligence; we believe that by automating this process, target-model building could become better and faster (contractors are currently developing such automated procedures). Again, this application software would most likely be developed for a particular PGW development program and would be part of its A/W/E module. This advanced capability is indicated by A/W/E+.

Although the A/W/E+ module would be hosted on AFMSS, an all-up AFMSS is not required at the central facility. Since only the target-model building portion of the A/W/E+ module will be needed, it might be possible to host this portion of the module onto another workstation, such as an AWS. The AWS would, of course, need the capability to import and export target models from and to AFMSS.

The ability of two central facility designs to produce target models, one using the above existing systems and the other using the above future systems, is assessed in subsequent chapters of this report.

DESIGN OPTION BASED ON CRUISE MISSILE SUPPORT ACTIVITIES

Currently, operational missions for the Navy Tomahawk cruise missile are built by personnel at two CMSAs, one under the operational control of Commander in Chief, U.S. Pacific Command, at Camp Smith, Hawaii, and the other under the operational control of

Commander in Chief, U.S. Atlantic Command, at Norfolk, Virginia. Both CMSAs rely on their Joint Intelligence Centers (JICs) for targeting support and for obtaining imagery not resident in their databases. With this support and with the support of DMA, the CMSAs produce en route data and terminal-area products to support Tomahawk employment. The en route data include missile commands, way points, and Terrain Contour Matching (TERCOM) maps. The TERCOM maps are produced by DMA and are used to update the inertial navigation system (INS) of the missile at designated locations along the planned route. Because this report is focused on terminal-area planning (in particular, target-model building), the report does not discuss CMSAs route planning systems and procedures any further.

To support terminal-area missile operations of current versions of Tomahawk, the CMSAs produce Digital Scene Matching Area Correlator (DSMAC) scenes, which allow the missiles to further update their INS in the vicinity of the target and achieve excellent delivery accuracy. The production of the DSMAC scenes requires access to a large imagery database.

The ongoing upgrade of the CMSAs with the Digital Imagery Workstation Suite (DIWS) could be used to support the terminal-area requirements of autonomous PGWs with target-imaging sensors.[6] Figure 2.3 depicts the four subsystems of DIWS: (1) the shared resource (SR) subsystem, (2) the image data input (IDI) subsystem, (3) the image data storage (IDS) subsystem, and (4) the workstations (WSs). For readers not familiar with DIWS, the system is described in some detail below to indicate the substantial data processing and storage capabilities (*Navy Training Plan*, 1992).

The SR subsystem is a VAX-based, high-speed processing system with peripherals. Its primary function is to control and manage tasks being performed throughout the system.

The IDI subsystem is a MICROVAX-based, multi-media input system for imagery, imagery support data, and databases. Both CMSAs cur-

[6]The Navy is currently investigating options for adding a target-imaging sensor to the next upgrade of Tomahawk, commonly known as Tomahawk Block IV. This capability is being investigated within the Tomahawk Block Improvement Program (TBIP).

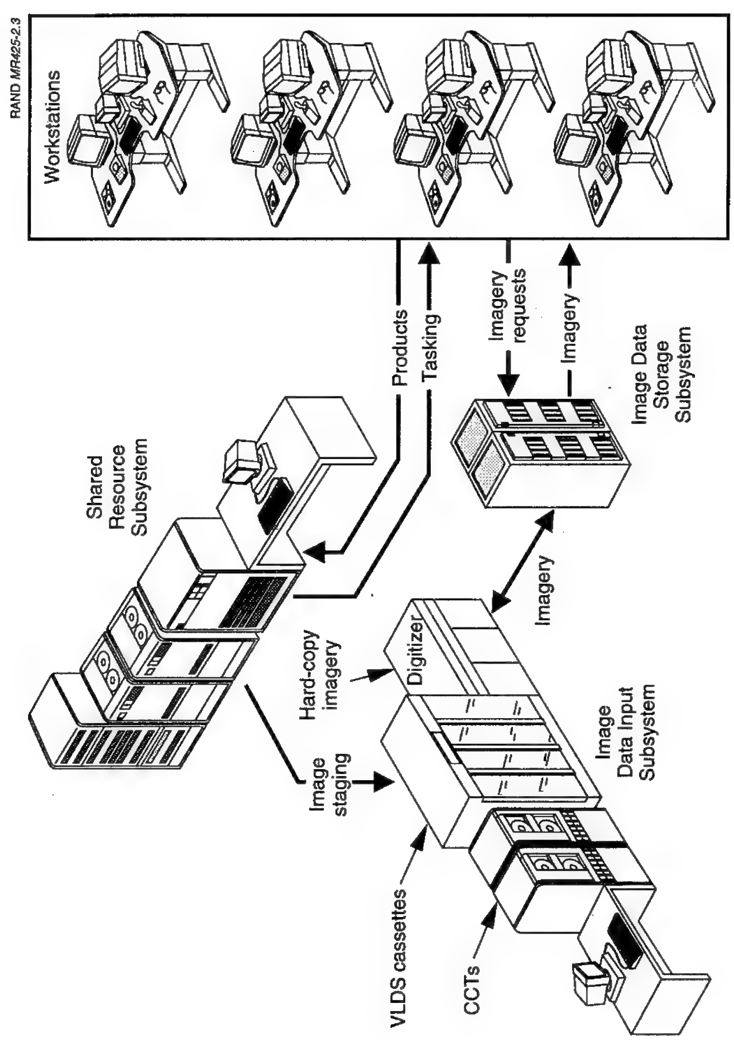


Figure 2.3—Digital Imagery Worstation Suite

rently receive such data from various sources. The IDI subsystem controls the reformatting of external image data to DIWS internal formats. Soft-copy imagery can be entered into the IDI subsystem from computer compatible tapes (CCTs) and very large data storage (VLDS) cassettes. Hard-copy imagery can be entered using a high-quality digitizer. The output from the IDI subsystem is only to VLDS cassettes. The IDS subsystem provides the principal storage for on-line data.

The workstation is the digital processing unit of the system for manipulating imagery and producing imagery products. Each workstation is controlled by a MICROVAX computer and several microprocessors for individual applications such as imagery rectification and annotation. The workstation includes a 1K by 1K color overview display and a 1K by 1K split-screen circularly polarized mensuration display for viewing stereo imagery. The DIWS can support up to six workstations. The workstations have software applications for both geopositioning and mensurating imagery.

Relying on *digitized* PPDBs (hard-copy PPDBs that are digitized) until DPPDBs become available, trained personnel at a CMSA could perform the targeting, geopositioning, and mensuration functions necessary to build target models on the workstations. With the installation of DIWS, the only additional capability required by CMSAs to support terminal-area planning for autonomous PGWs with target-imaging sensors would be the application software for building target models. As discussed above, this software would be hosted on AFMSS (or possibly on DIWS, if the software is portable).[7] In this option, we assume that advanced application software based on expert systems or artificial intelligence (i.e., A/W/E+) is available for building target models.

The estimated performance of a notional central facility based on CMSA systems is reflected in subsequent chapters of this report under the category of future systems; that is, the production capability of this option is the same as that based on the above centralized intelligence facilities using future systems.

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[7]The Navy may host similar software on DIWS or on the Tactical Aircraft Mission Planning System to support this category of PGW.

Chapter Three

BUILDING TARGET MODELS FOR PREPLANNED TARGETS

REQUIRED FUNCTIONS AND TIMELINES FOR BUILDING A SINGLE TARGET MODEL

The building of target models to support autonomous PGWs with target-imaging sensors requires the accomplishment of the following functions:

- Data (principally imagery) collection, if not available.
- Targeting: translation of operational objectives, target development, critical node identification, aimpoint selection, and weaponeering.
- Mensuration: measurement of the lengths, widths, heights, and orientations with respect to north of targets and contextual objects.
- Geopositioning: determination of the precise geodetic locations of targets and contextual objects.
- Target-model building: concept formulation, and formatting and entering data into a target folder.
- Quality control: reviewing procedures used in building target models and entering data into target folders.[1]

[1]Target template validation is not included in the quality-control process. (A target model is transformed by the PGW's terminal guidance system into a format, called a template, that is directly usable by the onboard correlation algorithm to acquire the

The imagery collection function refers to the collection of high-resolution, visible imagery, which is required for accurate and precise mensuration of targets and contextual objects. For terminal guidance systems that use imaging infrared sensors or synthetic aperture radars, infrared or radar imagery may also be useful for building target models; however, collection of such imagery is not assumed here. Contractors developing target-imaging sensors and autonomous target-acquisition algorithms are currently developing procedures for building target models that assume that visible imagery is the principal source of data and, therefore, they are incorporating a prediction or translation process (i.e., infrared and radar scene prediction procedures using visible imagery).

The estimated timelines for completing these tasks, using existing systems and procedures that are currently available in central facilities or using improved procedures and systems that could be available in the future, are shown in Table 3.1. As we subsequently discuss, the difference in timelines between using *existing* and *future* systems is primarily because the process of building target models with current systems is, for the most part, manual; whereas, with future systems, the process is more automated, using advanced software based on expert systems or artificial intelligence (i.e., A/W/E+) and hosted on AFMSS, DIWS, or an AWS.[2]

Also, the terms *simple* and *complex* used in Table 3.1 (and in subsequent tables) refer to the amount of clutter around the target. A *simple* target would be one located in a relatively uncluttered scene (i.e., there are just a few other structures around the target) and a *complex* target would be one located in a cluttered scene, such as an urban area.

The time to collect national imagery data varies widely and is primarily a function of the priority assigned to the collection requirements. A highest priority requirement may be satisfied in about

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target). Validation is the process used to determine, with some level of confidence, that the template is unique and that it will correctly identify the target in the imaged scene. As discussed in the companion report, validation is a major unresolved issue. At this time, it is uncertain what procedures are required or how long these procedures will take.

[2]The AWS is an advanced workstation, such as TMWS+ or LCWS.

Table 3.1

Estimated Timelines for Building a Single Target Model for Preplanned Targets

	Existing Systems		Future Systems	
Function	Simple (hr)	Complex (hr)	Simple (hr)	Complex (hr)
Data collection (in days)[a]	2-730	2-730	2-730	2-730
Targeting	1.00	4.00	1.00	4.00
Measurement				
Mensuration	0.67	0.83	N/A	N/A
Geopositioning	1.33	2.17	N/A	N/A
Subtotal	2.00	3.00	0.58	0.92
Target-model building[b]				
Concept formulation	1.00	3.00	0.50	1.50
Formatting/entering data	0.08	0.10	0.03	0.05
Subtotal	1.08	3.10	0.53	1.55
Quality control	0.32	0.93	0.16	0.46
Total (1 model)[c]	4.40	11.93	2.27	6.93

[a]Note that the values in this row are given in days, not hours.

[b]One approach azimuth, one time of day, one weather or seasonal condition.

[c]Assuming imagery exists on some targets to begin the process (i.e., there are no delays as a result of data collection) and *assuming serial production.*

two days,[3] whereas a routine priority requirement may not be satisfied within two years. Weather conditions over the area of interest may also affect collection capabilities. Also, it may take longer to satisfy collection requirements if stereo imagery is needed for accurate and precise mensuration and geopositioning.

Because of the wide time variability, in the following calculations we treat the data collection function as being performed in parallel with

[3]Collection assets, such as unmanned aerial vehicles, tailored to support autonomous PGWs with target-imaging sensors could be developed to shorten collection timelines. Also, the imagery could be collected at the wavelength of the target-imaging sensor.

the other functions; that is, production of target models is begun on targets for which imagery is available and imagery data collection is begun for the other targets. Thus, we assume that there is no delay for data collection for preplanned targets. Later, when we consider planning missions for emergent targets, we assume a two-day data collection delay.

Typically, the timelines associated with targeting can vary from about an hour to several days depending on the target. For very *difficult* targets, such as hardened and buried bunkers, the process may take a week or more. For *easy* targets, such as unprotected radar sites, targeting may be done in about an hour. For the majority of targets for which these autonomous PGWs are likely to be used, one to four hours is considered representative. To bracket timeline extremes (and to eliminate the number of target-type combinations), we will associate *easy* targets for targeting with *simple* targets for building target models; similarly, we will associate *difficult* targets for targeting with *complex* targets for building target models. This explains the column headings in Table 3.1.

Currently, imagery mensuration can be done on IDEX II (soft-copy imagery), on LTMS (hard-copy imagery), or manually with a ruler, protractor, and compass (target material graphics). The numbers shown in Table 3.1 assume that IDEX II is used to mensurate the target and contextual objects.[4] Mensuration takes about 40 min for a simple, uncluttered target and 50 min for a complex, cluttered scene. Most of this time (30 min) is consumed in retrieving the imagery from the database and loading it onto IDEX II. The actual mensuration takes about 2 min per object. A simple target would have approximately five objects (with no other objects in the vicinity of the target) to mensurate, which would take 10 min; a complex target would have approximately ten objects of interest (e.g., in an urban scene) to mensurate, which would take 20 min.

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[4]If LTMS is used for mensuration, the times will be longer than those listed in Table 3.1. If an AWS (e.g., TMWS+ or LCWS) is made available, the times would be comparable to those for IDEX II.

The geopositioning timeline estimates using existing systems are based on PPDBs and APPS.[5] Geopositioning takes about 80 min for simple targets and 130 min for complex targets. The estimates include 30 min to retrieve the PPDB from the database and to set up the APPS, and 10 min to geoposition one corner of each object of interest (five objects takes 50 min and ten objects takes 100 min).

Two development programs, RPC and DPPDBs (used either as the primary source of imagery or for controlling current imagery without RPC data), along with the necessary application software hosted on a digital imagery workstation,[6] will significantly reduce the timelines for mensuration and geopositioning. The estimates for performing these functions are shown in Table 3.1 under the future systems columns. These estimates include 15 min for accessing the appropriate current image with RPC data or the appropriate DPPDB, 2 min to geoposition a corner of an object, and 2 min to mensurate an object. The simple five-object target requires 10 min to geoposition and 10 min to mensurate for a total of 35 min; the complex ten-object target requires 20 min to geoposition and 20 min to mensurate for a total of 55 min.

Building target models involves two separate tasks. The first is concept or strategy formulation. This is the visualization, by a well-trained target-model builder, of which objects in the target area can be used to develop a unique target model that can then be used by the PGW's terminal guidance system (target-imaging sensor and autonomous target-acquisition algorithm) to identify the target in the imaged scene. Concept formulation is currently a manual process; there are no existing systems to assist the target-model builder. The completion of this task is assumed to take about 1 hr for the notional simple target and about 3 hr for the notional complex target. Although the process of building target models will be different for each type of target-imaging sensor, the corresponding timelines for

[5]If PPDBs are not available for particular targets, mensurated coordinates can be obtained from DMA through their Points Program. This process can take 30 days for normal production schedules.

[6]Example digital imagery workstations include an upgraded IDEX II, DIWS, or AWS (e.g., TMWS+ or LCWS).

completing this task are expected to be about the same.[7] Note that these are only *rough estimates* based on limited experience within the PGW development community with the performance of this task. The timelines associated with the mensuration and geopositioning of the selected objects have been discussed above.

The function of target-model building is completed when the second task, the formatting of the specific data used by the mission planning system and the entering of this data into target folders, by hand, is completed. Note that the amount of data required to define a target model is substantially less than that generated during concept formulation. This function takes about 5 to 6 min per model.

In the future, expert-system software for building target models could be developed. If hosted on (1) a mission planning workstation capable of soft-copy imagery manipulation, (2) a new LCWS (or perhaps on an upgraded TMWS), or (3) DIWS, this software may substantially reduce the concept formulation timelines and provide direct input to a data transfer device that would then be added to the target folder. If these improvements materialize, the timelines for concept formulation may reduce to about 0.5 hr for the notional simple target and to about 1.5 hr for the notional complex target. Similarly, the timeline for formatting and entering data may reduce to about 2 to 3 min per model.

Because a methodology for validating target models (or target templates) has not been developed, the quality control (QC) process is postulated to include only a review of the procedures used by the analyst in building the target model and a check on the data entered in the target-model folder. This process is estimated to take 30 percent as long as the actual target-model building.

Assuming that the targeting, mensuration, geopositioning, model building, and QC functions are performed as part of a *serial production process*, the total time required to build a target model for a single-PGW mission from one approach azimuth, for one particular

[7]Because the laser radar's autonomous target-acquisition algorithm relies principally on three-dimensional data about the target and does not require a scene prediction procedure (as do the imaging infrared sensor and the synthetic aperture radar) to develop target models, the timelines may be shorter for the laser radar.

time of day, and for one weather or seasonal condition using existing systems is about 4.5 hr for the notional simple target and 12 hr for the notional complex target. In the future, these times may be reduced to about 2.5 and 7 hr, respectively.

The functions necessary to complete the production of a target model do not have to be done *in series.* A production facility can be configured to perform the functions *in parallel.* Assuming parallel processing, the total time required to complete a target model is reduced to the time of the dominant (i.e., most time-consuming) function. When we describe target-model production rates in Chapter Five, we will use the results from the parallel production process; however, for completeness, we will continue to describe the serial production process.

Using existing systems, the dominant function for the notional simple target is mensuration and geopositioning, which takes about 2 hr; the dominant function for the notional complex target is targeting, which takes about 4 hr. Using future systems, the dominant function for both simple and complex targets is targeting, which takes about 1 hr and 4 hr, respectively. These numbers apply to the case when *only one* target model is built per target.

NUMBER OF TARGET MODELS FOR PREPLANNED MISSIONS

The number of specific target models that should be included in a target folder for a single target is a function of the flexibility needed by operators and a function of the type of target-imaging sensor. In our calculations, we used the following assumptions[8] to determine the number of target models that should be placed in a preplanned target folder for autonomous PGWs with imaging infrared sensors:

- Two approach azimuths
- Three times of day (i.e., morning, afternoon, night)

[8]These assumptions are based on our discussions with sensor contractors, representatives from the test community, and other analysts.

- Two weather or seasonal conditions (e.g., clear, high humidity, summer, winter, etc.)
- An additional aimpoint, known as an offset aimpoint, for multiple-PGW missions (i.e., twice as many models).

For operational flexibility, two approach azimuths are assumed. Because the infrared image of a target can change significantly during a 24-hr period, three times of day are assumed. Because the performance of an imaging infrared sensor is sensitive to weather and to scene variability because of seasonal conditions, two different weather or seasonal conditions are assumed.[9] Using these assumptions, 12 target models are required for preplanned, single-PGW missions and 24 target models for preplanned, multiple-PGW missions.[10]

If the target requires more than one PGW to achieve the desired level of damage (i.e., a multiple-PGW mission), target models for both an offset aimpoint and the nominal aimpoint are required. For autonomous PGWs with target-imaging sensors, changes to the target resulting from damage from preceding PGWs may adversely affect the ability of subsequent PGWs to acquire and hit the target. A reasonable approach to avoid this potential problem is to build the target models for the first PGW so that it actually *homes* on the target and to build the models for subsequent PGWs as offset-aimpoint missions, using an object or combination of objects in the vicinity of the target as an offset aimpoint. For offset-aimpoint missions to be effective, the location of the true aimpoint *relative* to the offset aimpoint must be known very accurately.

However, if only one PGW arriving at the target is sufficient to achieve the desired level of damage, but more than one PGW is used because of reliability or survivability issues, then only one set of target models needs to be built. Although this is a multiple-PGW mission, timelines for preplanned, single-PGW missions are appropriate.

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[9]The performance of infrared sensors is described in a number of books; for example, see Hudson (1969), Lloyd (1975), and Wolfe and Zissis (1985).

[10]For autonomous PGWs with laser radars, fewer models would be required because time of day is not an important consideration. For autonomous PGWs with synthetic aperture radars, even fewer models could be required because weather and seasonal conditions also may not be important considerations.

(If operators want to take advantage of the damage compounding provided by more than one PGW reaching the target, offset-aimpoint missions would be needed; we did not make this assumption in the following calculations.)

For operational flexibility, it may also be useful to build offset-aimpoint target models even for single-PGW missions. This would allow restrike of targets that did not suffer sufficient damage or that were not damaged at all (because of PGW survivability or reliability reasons or because the target was not acquired by the terminal guidance system of the first PGW). In the following calculations, we did not make this assumption.

BUILDING TARGET MODELS FOR PREPLANNED, SINGLE-PGW MISSIONS

The timelines for building target models for a preplanned, single-PGW mission are the sum of the times to build the first target model (one approach azimuth, one time of day, and one weather or seasonal condition) and the other 11 models. The timelines for building subsequent target models will be, on the average, substantially shorter than the timelines for the first target model, because concept formulation for subsequent models is likely to be less time-consuming and the targeting, geopositioning, and mensuration functions do not have to be redone. We have also assumed that building target models for another approach azimuth is more time-consuming than for another time of day or another weather or seasonal condition. Our estimates for building the 12 target models for preplanned, single-PGW missions are shown in Table 3.2; again, these are *rough estimates.*

Assuming *serial processing* and using existing systems, the timelines to produce target models for a preplanned, single-PGW mission are roughly 9.5 hr for a simple target and about 21 hr for a complex target. If postulated future systems and software become available, the preceding times may be reduced to roughly 4.5 hr and 12 hr, respectively. For *parallel processing,* the dominant function in all cases is target-model building: Using existing systems, the timelines are about 5 hr and 10.5 hr for simple and complex targets, respectively;

Table 3.2

Estimated Timelines for Preplanned, Single-PGW Missions

	Existing Systems		Future Systems	
Function	Simple (hr)	Complex (hr)	Simple (hr)	Complex (hr)
Targeting	1.00	4.00	1.00	4.00
Measurement				
Mensuration	0.67	0.83	N/A	N/A
Geopositioning	1.33	2.17	N/A	N/A
Subtotal	2.00	3.00	0.58	0.92
Target-model building				
Concept formulation				
First approach/first weather or seasonal condition				
First time of day	1.00	3.00	0.50	1.50
Second time of day	0.25	0.50	0.125	0.25
Third time of day	0.25	0.50	0.125	0.25
First approach/second weather or seasonal condition				
First time of day	0.25	0.50	0.125	0.25
Second time of day	0.25	0.50	0.125	0.25
Third time of day	0.25	0.50	0.125	0.25
Second approach/first weather or seasonal condition				
First time of day	0.50	1.50	0.25	0.75
Second time of day	0.25	0.50	0.125	0.25
Third time of day	0.25	0.50	0.125	0.25
Second approach/second weather or seasonal condition				
First time of day	0.25	0.50	0.125	0.25
Second time of day	0.25	0.50	0.125	0.25
Third time of day	0.25	0.50	0.125	0.25
Subtotal	4.00	9.50	2.00	4.75
Formatting/entering data	1.00	1.20	0.40	0.60
Subtotal[a]	**5.00**	**10.70**	**2.40**	5.35
Quality control	1.50	3.21	0.72	1.60
Total (12 models)[b]	9.50	20.91	4.70	11.87

[a]Target-model building is the dominant function (i.e., most time-consuming); these values *apply to parallel production.*

[b]Assuming imagery exists on some targets to begin the process (i.e., there are no delays as a result of data collection) and *assuming serial production.*

using future systems, the timelines are about 2.5 hr and 5.5 hr for simple and complex targets, respectively.

BUILDING TARGET MODELS FOR PREPLANNED, MULTIPLE-PGW MISSIONS

The timelines for building target models for multiple-PGW missions requiring offset aimpoints are the sum of the times to (1) build the target model for the first PGW, (2) build the target models for the offset-aimpoint PGWs, and (3) format and enter the data for the first and all subsequent PGWs into the target folder. Table 3.3 lists the estimated timelines for completing the 24 target models for preplanned, multiple-PGW missions; these are *rough estimates.*

The following assumptions were used in developing these timelines:

- The targeting, mensuration, and geopositioning functions done for the first set of target models (first PGW) are sufficient to build offset-aimpoint target models.
- The concept formulation done for the first set of target models reduces the time required for concept formulation for the offset-aimpoint target models (the timeline is estimated to be 3 hr using existing systems and 1.5 hr using future systems).
- The offset-aimpoint target models built for the second PGW are used for all subsequent PGWs.

Assuming *serial processing* and using existing systems, the timelines to produce target models for a preplanned, multiple-PGW mission are roughly 14.5 hr for a simple target and about 26 hr for a complex target. If postulated future systems and software become available, the preceding times may be reduced to roughly 7 and 14.5 hr, respectively. For *parallel processing,* the dominant function in all cases is target-model building: Using existing systems, the timelines are about 9 hr and 15 hr for simple and complex targets, respectively; using future systems, the timelines are about 4.5 hr and 7.5 hr for simple and complex targets, respectively.

Table 3.3

Estimated Timelines for Preplanned, Multiple-PGW Missions Requiring Offset Aimpoints

	Existing Systems		Future Systems	
Function	Simple (hr)	Complex (hr)	Simple (hr)	Complex (hr)
Targeting	1.00	4.00	1.00	4.00
Measurement				
Mensuration	0.67	0.83	N/A	N/A
Geopositioning	1.33	2.17	N/A	N/A
Subtotal	2.00	3.00	0.58	0.92
Target-model building				
Target models for first PGW				
Concept formulation	4.00	9.50	2.00	4.75
Formatting/entering data	1.00	1.20	0.40	0.60
Subtotal	5.00	10.70	2.40	5.35
Target models for offset aimpoint[a]				
Concept formulation	3.00	3.00	1.50	1.50
Formatting/entering data	1.00	1.10	0.40	0.60
Subtotal	4.00	4.10	1.90	2.10
Subtotal[b]	**9.00**	**14.80**	**4.30**	**7.45**
Quality control	2.70	4.44	1.29	2.24
Total (24 models)[c]	14.70	26.24	7.17	14.61

[a]These target models are used by the second and any subsequent PGWs.

[b]Target-model building is the dominant function (i.e., most time-consuming); these values *apply to parallel production.*

[c]Assuming imagery exists on some targets to begin the process (i.e., there are no delays as a result of data collection) and *assuming serial production.*

Chapter Four

BUILDING TARGET MODELS FOR EMERGENT TARGETS

REQUIRED FUNCTIONS AND TIMELINES FOR BUILDING A SINGLE TARGET MODEL

Emergent targets are defined as those targets assigned to PGWs for which there are no preplanned target models and for which the necessary imagery has not been collected and provided to the central facility. Therefore, all the functions listed in Table 3.1 have to be completed to produce the required target models. This means that the dominant timeline for producing the target models can be imagery collection; we use a value of two days, assuming that very high priority is assigned to collect and deliver the requisite imagery to the central production facility.

However, this postulated time for data collection should be included in the total timeline for building target models for an emergent target only if adequate imagery is not available at the time of mission tasking. Often, intelligence and operations personnel responsible for targeting and air tasking order (ATO) development identify emergent targets from imagery. If this imagery is adequate for building target models and is provided to builders, the time for data collection should not be included in the total timeline.

Even if adequate imagery is not available for emergent targets, it is very likely that imagery for more than one target can be collected during the two-day period. Assuming collection requirements are not excessive (i.e., there are a limited number of emergent targets identified per day), this timeline essentially becomes a two-day delay in target model production. On day three, target model production

begins, although it may be limited by the daily production rate for contingencies.

As shown in Table 4.1, using existing systems and assuming imagery is not available, the production of the first emergent target model (one approach azimuth, one time of day, and one weather or seasonal condition) for a simple target takes roughly 52.5 hr and for a complex target takes about 59 hr. Using future systems, these values become roughly 50.5 hr and 55 hr, respectively. In both cases, the timeline is dominated by imagery collection.

Table 4.1

Estimated Timelines for Building a Single Target Model for Emergent Targets

	Existing Systems		Future Systems	
Function	Simple (hr)	Complex (hr)	Simple (hr)	Complex (hr)
Data collection[a]	48.00	48.00	48.00	48.00
Targeting	1.00	4.83	1.00	4.00
Measurement				
Mensuration	0.67	0.83	N/A	N/A
Geopositioning	1.33	2.17	N/A	N/A
Subtotal	2.00	3.00	0.58	0.92
Target-model building[b]				
Concept formulation	1.00	3.00	0.50	1.50
Formatting/entering data	0.08	0.10	0.03	0.05
Subtotal	1.08	3.10	0.53	1.55
Quality control	0.54	0.93	0.16	0.46
Total (1 model)[c]	52.62	59.03	50.27	54.93

[a]The postulated time shown for data collection should be included in the total timeline for building target models for emergent targets only if adequate imagery is not available at the time of mission tasking.

[b]One approach azimuth, one time of day, one weather or seasonal condition.

[c]Assuming no imagery exists for emergent targets and *assuming serial production.*

NUMBER OF TARGET MODELS FOR EMERGENT MISSIONS

The number of specific target models that should be included in a target folder for an emergent target is a function of the flexibility needed by operators and the type of target-imaging sensor. A smaller number of target models is likely to be required for emergent targets than for preplanned targets. In particular, weather and seasonal conditions are likely to be known. This would reduce the number of target models for single-PGW missions from 12 models for preplanned missions to 6 models for emergent missions. Similarly, the number of target models for multiple-PGW missions is reduced from 24 models for preplanned missions to 12 models for emergent missions. If the operator can accept less flexibility (i.e., fewer times of day or approach azimuths), the number of target models can be further reduced.

In summary, we used the following assumptions:

- Two approach azimuths
- Three times of day (i.e., morning, afternoon, night)
- One weather/seasonal condition (e.g., clear winter day, high-humidity summer day)
- An additional aimpoint (an offset aimpoint) for multiple-PGW missions.

BUILDING TARGET MODELS FOR EMERGENT, SINGLE-PGW MISSIONS

The timelines for building an emergent, single-PGW mission are the sum of the times to build the first target model (one approach azimuth, one time of day, and one weather/seasonal condition) and the other five models. The timelines for building subsequent target models will be, on the average, substantially shorter than the timelines for the first target model, because concept formulation for subsequent models is likely to be less time-consuming and the targeting, geopositioning, and mensuration functions do not have to be redone. We have also assumed that building target models for another approach azimuth is more time-consuming than for another time or

day or weather or seasonal condition. Our estimates for building the six target models for emergent, single-PGW missions are shown in Table 4.2.

Table 4.2

Estimated Timelines for Emergent, Single-PGW Missions

	Existing Systems		Future Systems	
Function	Simple (hr)	Complex (hr)	Simple (hr)	Complex (hr)
Data collection[a]	48.00	48.00	48.00	48.00
Targeting	1.00	4.83	1.00	**4.00**
Measurement				
Mensuration	0.67	0.83	N/A	N/A
Geopositioning	1.33	2.17	N/A	N/A
Subtotal	2.00	3.00	0.58	0.92
Target-model building				
Concept formulation				
First approach				
First time of day	1.00	3.00	0.50	1.50
Second time of day	0.25	0.50	0.125	0.25
Third time of day	0.25	0.50	0.125	0.25
Second approach				
First time of day	0.50	1.50	0.25	0.75
Second time of day	0.25	0.50	0.125	0.25
Third time of day	0.25	0.50	0.125	0.25
Subtotal	2.50	6.50	1.25	3.25
Formatting/entering data	0.50	0.60	0.20	0.30
Subtotal[b]	**3.00**	**7.10**	**1.45**	3.55
Quality control	0.90	2.13	0.44	1.06
Total (6 models)[c]	54.90	64.23	51.47	57.53

[a]The postulated time shown for data collection should be included in the total timeline for building target models for emergent targets only if adequate imagery is not available at the time of mission tasking.

[b]Target-model building is the dominant function (i.e., most time-consuming); these values *apply to parallel production* except for the entry in the last column. In that case, the dominant function is targeting.

[c]Assuming no imagery exists for emergent targets and *assuming serial production.*

Assuming *serial processing* and using existing systems, the timelines to produce target models for an emergent, single-PGW mission are roughly 55 hr for a simple target and about 64 hr for a complex target. If postulated future systems and software become available, the preceding times may be reduced to roughly 51.5 hr and 57.5 hr, respectively. In both timelines, imagery collection dominates. For *parallel processing*, the dominant function (ignoring data collection) in most cases is target-model building: Using existing systems, the timelines are about 3 hr and 7 hr for simple and complex targets, respectively; using future systems, the timelines are about 1.5 hr and 4 hr for simple and complex targets, respectively (the last value is dominated by targeting).

BUILDING TARGET MODELS FOR EMERGENT, MULTIPLE-PGW MISSIONS

The timelines for building target models for multiple-PGW missions requiring offset aimpoints are the sum of the times to (1) build the target model for the first PGW, (2) build the target models for the offset-aimpoint PGWs, and (3) format and enter the data for the first and all subsequent PGWs into the target folder. Table 4.3 lists the estimated timelines for completing the 12 target models for emergent, multiple-PGW missions.

The following assumptions were used in developing these timelines:

- The targeting, mensuration, and geopositioning functions done for the first set of target models (first PGW) are sufficient to build offset-aimpoint target models.
- The concept formulation done for the first set of target models reduces the time required for concept formulation for the offset-aimpoint target models (the timeline is estimated to be 2 hr using existing systems and 1 hr using future systems).
- The offset-aimpoint target models built for the second PGW are used for all subsequent PGWs.

Assuming *serial processing* and using existing systems, the timelines to produce target models for an emergent, multiple-PGW mission are roughly 58 hr for a simple target and about 67.5 hr for a complex

Table 4.3

Estimated Timelines for Emergent, Multiple-PGW Missions Requiring Offset Aimpoints

	Existing Systems		Future Systems	
Function	Simple (hr)	Complex (hr)	Simple (hr)	Complex (hr)
Data collection[a]	48.00	48.00	48.00	48.00
Targeting	1.00	4.00	1.00	4.00
Measurement				
Mensuration	0.67	0.83	N/A	N/A
Geopositioning	1.33	2.17	N/A	N/A
Subtotal	2.00	3.00	0.58	0.92
Target-model building				
Target models for first PGW				
Concept formulation	2.50	6.50	1.25	3.25
Formatting/entering data	0.50	0.60	0.20	0.30
Subtotal	3.00	7.10	1.45	3.55
Target models for offset aimpoint[b]				
Concept formulation	2.00	2.00	1.00	1.00
Formatting/entering data	0.50	0.60	0.20	0.30
Subtotal	2.50	2.60	1.20	1.80
Subtotal[c]	**5.50**	**9.70**	**2.65**	5.35
Quality control	1.65	2.91	0.78	1.61
Total (12 models)[d]	58.15	67.61	53.01	59.88

[a]The postulated time shown for data collection should be included in the total timeline for building target models for emergent targets only if adequate imagery is not available at the time of mission tasking.

[b]These target models are used by the second and any subsequent PGWs.

[c]Target-model building is the dominant function (i.e., most time-consuming); these values *apply to parallel production.*

[d]Assuming no imagery exists for emergent targets and *assuming serial production.*

target. If postulated future systems and software become available, the preceding times may be reduced to roughly 53 and 60 hr, respectively. Again, imagery collection dominates the timelines. For *parallel processing,* the dominant function (ignoring data collection) in all cases is target-model building. Using existing systems, the time-

lines are about 5.5 hr and 9.5 hr for simple and complex targets, respectively; using future systems, the timelines are about 2.5 hr and 5.5 hr for simple and complex targets, respectively.

Chapter Five

PRODUCING TARGET MODELS AT A CENTRAL FACILITY

Producing target models at a notional central facility can be discussed in terms of (1) peacetime operations—supporting the readiness of PGW-capable wings based in CONUS or developed theaters for deployment to regions of high interest, by producing preplanned target models, and (2) contingency support operations—supporting the sustained capability of PGW-capable wings deployed in the theater of operations, by continuing production of target models for preplanned targets and initiating production of target models for emergent targets, all in response to the supported commander in chief's (CINC's) priority.

In peacetime, the central facility would provide PGW wings with target models for preplanned targets on a to-be-defined schedule. In support of contingencies, central facilities would use robust communication channels to provide PGW wings with target models of preplanned and emergent targets. Data dissemination could include both target models and imagery, although only target models are required to support PGW employment. The next subsection discusses the personnel and systems we believe will be needed at the central facility to build target models.

POSTULATED RESOURCES FOR BUILDING TARGET MODELS

The number of target models that a central facility can produce is primarily a function of (1) the number and type of personnel and

systems assigned to the facility and (2) the operating protocols of the facility (the time available to support target-model building).

Currently, the targeting function and the mensuration and geopositioning functions are typically performed by different individuals. Targeteers are trained to do targeting. Imagery analysts are trained to do mensuration and geopositioning. The function of building target models requires yet another well-trained individual, one who understands the operations of the target-imaging sensor and the autonomous target-acquisition algorithm (see the discussion on training in Hura and McLeod, 1993).

For our analysis of the peacetime target-model production capability for preplanned targets at a central facility, we assume that

- 30 personnel are assigned to support target-model production.
- The personnel are assigned to three, ten-man watch sections (two targeteers, two imagery analysts, four target-model builders, one quality control person, and one supervisor).
- Two watch sections are available to work two eight-hour shifts per day (the equivalent of one watch section is at school, on temporary duty, or on leave).
- Each watch section spends seven out of the eight hours actually performing PGW-support functions.
- Target-model building is accomplished using parallel production, with the dominant function determining the timeline.

Because the dominant function (i.e., the most time-consuming) function is usually target-model concept formulation, more target-model builders are included per watch section than imagery analysts or targeteers.

Using the preceding assumptions, 56 hours per day are available for building target models (four target-model builders × two shifts × seven hours per shift).

To effectively use the assigned personnel, the following equipment (relying on existing systems) has to be available for 14 hr per day:

two IDEX II workstations and two APPS; these systems will support the imagery analysts.[1] It is assumed that targeting and target-model building will be done manually and therefore do not require any new systems. However, manuals containing the procedures for building the target models will be required.

In the future, the notional central facility may be equipped with two AWS (e.g., TMWS+ or LCWS) with imagery mensuration and geopositioning software to support the imagery analysts and two AFMSS (each with two seats) with an advanced software module (i.e., A/W/E+) to support the target-model builders. These future systems would allow the central facility to reduce the time required to build target models by about a factor of two.

AFMSS was added to the central facility because it will be the Air Force's common automated mission planning system and will therefore host the modules to support the automated mission planning of advanced PGWs. If, in the future, a single workstation is developed that can do imagery mensuration, geopositioning, and target-model building (i.e., the PGW-specific software is rehosted from AFMSS onto the workstation), then AFMSS would not be needed at the central facility, but the new workstation must be able to load target models onto a data transfer device that is compatible with AFMSS. In addition, it then may be more appropriate for a single individual to perform all these functions; rather than splitting them between an imagery analyst and a target-model builder (as currently assumed). In this case, if six analysts, each trained in imagery analysis and target-model building, replace the two imagery analysts and four target-model builders, then six workstations must be made available. The dominant timeline for parallel production would now be longer because it would include mensuration and geopositioning as well as target-model building; however, the number of hours per day available for production would increase because six analysts are available instead of four. Since this combined workstation is not the baseline future system, we did not analyze this case any further.

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[1]LTMS may also be available for imagery mensuration; however, the mensuration times will be longer than those for IDEX II. An AWS (e.g., TMWS+ or LCWS) or a DIWS could replace the IDEX II, but the mensuration timelines would not change significantly.

PRODUCING TARGET MODELS FOR PREPLANNED TARGETS

We postulate that in peacetime and noncrisis situations, the notional central facility would build target models for preplanned targets. It would request routinely the necessary imagery to build target models for preplanned targets and operate on a production schedule that reflects supported CINC's target priorities.

The timelines for the dominant function for building preplanned target missions (from Tables 3.2 and 3.3) are summarized in Table 5.1.

Therefore, under the preceding resource assumptions, the number of preplanned target missions per day for which target models can be built at a notional central facility using existing systems is shown in Table 5.2 (the results from Table 5.1 are divided into the 56 hours per day available for target building).

The results presented in Table 5.2 can be used to calculate the number of days required to build target models for a specified number of preplanned targets. For example, using existing systems, one central facility could build the required number of target models for 1000

Table 5.1

Dominant Timelines for Preplanned Target Missions (hr)

	Existing Systems		Future Systems	
Mission Type	Simple	Complex	Simple	Complex
Single-PGW mission	5.00	10.70	2.40	5.35
Multiple-PGW mission	9.00	14.80	4.30	7.45

Table 5.2

Number of Preplanned Target Missions per Day

	Existing Systems		Future Systems	
Mission Type	Simple	Complex	Simple	Complex
Single-PGW mission	11.2	5.2	23.3	10.5
Multiple-PGW mission	6.2	3.8	13.0	7.5

simple-target, single-PGW missions in about 89 working days or for 1000 complex-target, multiple-PGW missions in about 265 working days.

PRODUCING TARGET MODELS FOR EMERGENT TARGETS

If requested by the supported CINC, the notional central facility can also build target models for emergent targets. The major difference in building target models for emergent targets rather than preplanned targets is that for the first set of emergent targets a sensor has to be tasked to collect the necessary imagery, and then the imagery has to be distributed to the central facility before parallel production of target models can begin. Assuming that this process for the initial set of emergent targets takes two days, the central facility can begin providing target models for emergent targets on the third day following the CINC's request. For subsequent emergent targets, imagery collection would continue in parallel with the other functions necessary to build target models; that is, the central facility could begin building missions on the third day following collection.

The timelines for the dominant function (not including imagery collection) for building emergent target missions (from Tables 4.2 and 4.3) are summarized in Table 5.3.

Therefore, under the preceding resource assumptions, the number of emergent target missions per day for which target models can be built at a notional central facility using existing systems is shown in Table 5.4 (the results from Table 5.3 are divided into the 56 hours per day available for target building).

Table 5.3

Dominant Timelines for Emergent Target Missions (hr)

	Existing Systems		Future Systems	
Mission Type	Simple	Complex	Simple	Complex
Single-PGW mission	3.00	7.10	1.45	4.00
Multiple-PGW mission	5.50	9.70	2.65	5.35

Table 5.4

Number of Emergent Target Missions per Day (starting on day three)

	Existing Systems		Future Systems	
Mission Type	Simple	Complex	Simple	Complex
Single-PGW mission	18.6	7.9	38.6	15.7
Multiple-PGW mission	10.2	5.8	21.3	10.5

Chapter Six

COST ESTIMATES FOR A NOTIONAL CENTRAL FACILITY

The costs of a central facility fall into two categories: (1) initial system procurement cost and (2) annual personnel and equipment support costs. Table 6.1 lists *rough estimates* for a notional central facility equipped with existing systems or future systems.

The existing system procurement cost includes $0.4 million for two IDEX II workstations (dedicated to PGW support) and $0.2 million for a robust, secondary imagery and data dissemination system. The workstation cost estimate assumes that applicable software and peripherals (database storage, file servers, digitizer, etc.) of the IDEX II at existing central facilities support these added workstations. We

Table 6.1

Cost Estimates for a Notional Central Facility

Item	Existing Systems	Future Systems
Initial procurement ($M)	0.6[a]	1.0
Annual support ($M/yr)		
System support	0.1	0.2
Personnel	3.0	3.0
Total	3.1	3.2

[a]If a memorandum of agreement is established that allows the central facility to use existing IDEX II workstations, this cost would decrease to $0.2 million. A similar cost reduction would result if prototype, low-cost, digital imagery workstations are provided by the TALON SCENE initiative.

are procuring a robust dissemination system because recent experience demonstrated that existing secondary imagery dissemination systems are inadequate. We assume that two APPS dedicated to PGW support are available at the central facility. The yearly personnel cost assumes that the central facility is manned with 30 trained personnel, each costing, on the average, $0.1 million per year.

Future systems procurement cost includes $0.4 million for two LCWS with imagery mensuration and geopositioning software (including RPC and DPPDB application software), $0.4 million for two AFMSS (each with two seats) with an advanced software module for building target models (i.e., A/W/E+), and $0.2 million for a robust, secondary imagery and data dissemination system (if not already procured). The increase in support cost reflects the added support for the AFMSS systems.

If the central facility is created within an existing facility that receives imagery only by courier, then additional costs (not included here) would be required to procure satellite communication receive capability and, perhaps, assign additional personnel to support the added systems. This capability is needed to support the building of target models for emergent targets in a responsive manner.

The cost values presented in this chapter assume that the target-model production rates discussed in Chapter Five are acceptable to operators. If these rates must be doubled (or tripled), then the system procurement cost and annual system support and personnel costs must also be doubled (or tripled).

Chapter Seven

CONCLUSIONS

The end-to-end process for building target models to support the mission planning of autonomous PGWs with target-imaging sensors is complex and requires the completion of several time-consuming functions. The process consists of the following functions: (1) data collection, (2) targeting, (3) imagery geopositioning and mensuration, (4) target-model building (concept formulation, and formatting and entering data into target folders), and (5) quality control.

The timelines for completing the preceding functions vary substantially as a function of (1) priority assigned to the target, (2) target complexity, (3) number of PGWs required to attack a target, and (4) the type of systems employed to build target models. For example, imagery data collection may vary from 2 to 730 days depending on the priority assigned to the target. Targeting may vary from 1 to 4 hr, depending on the complexity of the target. Similarly, using existing systems, the times to build target models for a mission against a preplanned target may vary from about 5 hr for a simple target requiring one PGW to about 15 hr for a complex target requiring multiple PGWs.

The notional central facility, built on existing systems at a centralized intelligence center, could produce target models to support the employment of autonomous PGWs with target-imaging sensors against 11 preplanned simple targets or 5 preplanned complex targets per day, assuming that these targets are single-PGW targets. If improved geopositioning and imagery mensuration capabilities and improved procedures for target-model building are provided to a centralized intelligence facility (i.e., future systems), its target-model building

capabilities for the same category of targets would roughly double. The target-model production rate can be increased if system procurement cost and annual system support and personnel costs are increased proportionately.

Because of the complexity of the tasks and the variation of times required to complete the tasks, a methodology for assessing the capabilities (both systems and personnel) of various facilities to support target-model building must explicitly consider each function and develop time estimates to complete each function under a range of conditions. The methodology presented in this report illustrates how this can be done in the context of a notional central facility.

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